Living With A Star TR&T
Abstracts of Selected Sun Climate Proposals
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Sun Climate

Scott England/University of California, Berkeley
Impact of the 11 Year Solar Cycle on the Gravity Wave Driven Circulation

Understanding the coupling of solar-variability to climate is a challenge that must be met to gauge the response of the climate to both natural and anthropogenic forcing. It is a complex problem and we do not yet understand several of the critical physical and chemical pathways within the atmosphere through which this coupling may be channeled. These pathways can involve interactions across multiple altitude regions of the atmosphere. Circulation driven by gravity waves plays an important role in coupling the middle atmosphere to the upper atmosphere and is likely sensitive to solar-cycle variations, thus playing an important role in solar-climate coupling. Here we detail a three-year modeling study to investigate the effect of the solar-cycle on gravity waves and the mesospheric circulation using the Whole Atmosphere Community Climate Model (WACCM). We have assembled a team with the experience in modeling gravity waves, atmospheric circulation and extensive experience of using WACCM. Preliminary model results offer encouragement that significant progress in our understanding of this can be made using a comprehensive atmospheric model and WACCM is a prime candidate. This model includes all of the components essential to study these effects meaningfully because it simulates the impact of the solar-cycle on both stratospheric O3 and planetary wave propagation, and also simulates gravity wave effects throughout the mesosphere. We will identify which regions respond most strongly to the solar input, how these impacts vary with altitude and period of the waves and how these effects vary with season. We will identify the relationship between changes in gravity wave activity and planetary wave activity at lower altitudes. This study will lay a crucial framework for further investigations by identifying which observational parameters associated with gravity wave activity offer the most robust constraints on the simulation of solar-cycle effects on gravity wave activity. This work is essential for understanding both how the whole wave-driven residual circulation in the middle atmosphere responds to the solar cycle and how this may influence other processes such as the transport of NOx to lower altitudes.

Charles Jackman/NASA Goddard Space Flight Center
Atmospheric Effects of Solar Proton Events and Galactic Cosmic Rays and Galactic Cosmic Rays

The proposed work will extend studies begun three years ago under the LWS investigation entitled "Long-term Atmospheric Effects of Solar Proton Events and their Contribution to the Polar Solar Cycle Variations." The proposed work will provide further quantification on solar proton events (SPEs) and their atmospheric influence. The work will also quantify the chemical influence on the atmosphere from galactic cosmic rays (GCRs). The objectives of this effort will be to answer the following questions:

1) How do SPE effects on middle atmospheric ozone depend on high-latitude interannual dynamical variability?

2) How does the upper mesosphere respond to SPE-induced changes in the middle atmosphere, including the effect on polar mesospheric clouds?

3) How do GCRs influence the chemical composition of the atmosphere over decadal time-scales?

We will use a global model, the NCAR Whole Atmosphere Community Climate Model (WACCM), as well as satellite measurements to address these questions. WACCM is a global chemistry climate model, whose domain extends from the ground to about 140 km. WACCM includes the chemistry and physics of the troposphere, stratosphere, mesosphere, and lower thermosphere and incorporates a module for the computation of polar mesospheric clouds. WACCM can also be utilized in a new 'Specified Dynamics' version (SD-WACCM), which is driven by assimilated winds and temperatures, to more closely reproduce actual dynamical conditions for particular time periods. This will enable us to better separate the impacts of SPEs and GCRs from other atmospheric variations for specific time periods.

Previously computed daily average ion pair production rates for SPEs, which were calculated from proton flux data, will be used in studies addressing the first two questions. The third question will be addressed with ionization rates for GCRs from the NASA Langley Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) investigation.

The proposed work is directly relevant to the Living With a Star Sun Climate Theme. It will improve the understanding of how SPEs and GCRs impact the middle atmosphere, whose coupling with the troposphere can influence the climate system.

Fabrizio Sassi/Naval Research Laboratory
Impacts of Stratospheric Dynamics on Atmospheric Behavior from the Ground to Space under Solar Minimum and Solar Maximum Conditions

Dynamical response to solar radiative forcing is a crucial and poorly understood mechanisms. We propose to study the impacts of large dynamical events on both the troposphere and the thermosphere during different phases of the solar cycle. The scientific objectives of this proposed research are intimately connected with the integrated response of the whole atmosphere to solar variability. In particular we compute and analyze the solar-induced variations of the following: (1) the penetration into the thermosphere of wave dynamics associated with disturbed events in the stratosphere; and (2) the influence of the stratosphere on the tropospheric climate during different phases of the solar cycle. In addition, a third objective of our research plan is to provide a fiducial simulation of the whole atmosphere up to 500 km which will allow the community to investigate in detail the sources and mechanisms that generate seasonal variations in the thermosphere (annual and semiannual variations). For this purpose, we will exercise the newly developed and updated extension of the Whole Atmosphere Community Climate Model (WACCM-X) to 500 km which provides the most comprehensive ground-to-thermosphere modeling capacity to date. To specify the stratospheric dynamical events as realistically as possible, the meteorology of the atmosphere below 90 km is constrained to the observed state using data assimilation products from the Naval Research Laboratory Atmospheric Variational Data Assimilation System (NAVDAS) or from the NASA Modern Era Retrospect Analysis for Research and Applications (MERRA). The quality of the model simulations (thus constrained) in the thermosphere will be assessed by comparing to the globally averaged mass density dataset developed at Naval Research Laboratory that covers the last 40 years and, where available, to composition, temperature and density profiles from the Global Ultraviolet Imager (GUVI) onboard of the NASA/TIMED satellite.

William Swartz/Johns Hopkins University/Applied Physics Laboratory
The Impact of Spectral Solar Irradiance Variations on the Atmosphere and Climate: Model Simulations and Observations

We propose a coordinated analysis of atmospheric observations and targeted simulations obtained from a state-of-the-art atmospheric chemistry and climate model in order to quantify the impact of solar output variations on global climate over a wide range of timescales, including both direct and indirect effects of the solar cycle and the spectral dependence of the solar irradiance. This proposed work addresses several objectives of the Living With a Star Targeted Research and Technology program. Two spectral solar irradiance (SSI) datasets will be used in this investigation: (1) a reconstruction (Lean et al.) based on satellite observations, long-term proxies of solar activity, and a solar model, and (2) SSI from the partial solar cycle observed by the SOlar Radiation & Climate Experiment (SORCE) inferred for a complete solar cycle. These SSI datasets are quite different in the amplitude and phase of their spectral dependence. Recent studies based on these datasets show that the Lean and SORCE SSI can produce very different atmospheric and climate responses in models, and initial comparisons with observations of stratospheric temperature and ozone appear more consistent with the SORCE SSI. There are inconsistencies between the recent studies in the patterns of atmospheric response, however. What other fingerprints of solar cycle response can be confirmed by observations in order to clarify our understanding of this problem? What are the implications for solar cycle sensitivities under different atmospheric conditions, such as pre-industrial times?

Using the Goddard Earth Observing System Chemistry-Climate Model (GEOS CCM), with fully coupled radiation-dynamics-chemistry, we will investigate the atmospheric response to the 11-year solar cycle as represented by the Lean and SORCE SSI. We will: (1) Investigate the mechanism of the 11-year solar cycle on direct atmospheric heating and photolysis. (2) Simulate stratospheric responses to the Lean and SORCE SSI datasets and compare the model output with satellite and ground-based observations of ozone, temperature, and other constituents to determine which view of the SSI is more consistent with observations. (3) Extend the investigation into the troposphere and compare model output with observations for evidence of the solar cycle and its mechanism(s) of impact. (4) Simulate the sensitivity of the atmospheric response to solar cycle variations under atmospheric conditions representative of earlier eras (e.g., pre-CFCs, pre-industrial). This sensitivity study will allow us to infer historical solar cycle effects, such as during the Maunder Minimum.

Guoyong Wen/Morgan State University
Investigation of Climate Response to Solar Spectral Variability on Decadal, Centennial, and Millennium Time Scales

This investigation is in the category of the Sun-Climate Theme of the Living With a Star (LWS) Program. We propose to evaluate the spectral details necessary for proper treatment of the radiative and photochemical response to solar spectral variability in climate models, and to investigate climate responses to solar spectral variability for a range of time scales ranging from decadal to centennial to millennial time scales. We will apply the existing coupled ocean-atmosphere radiative convective model (RCM) and GISS GCM Model 3 (GCMAM) to different spectral solar forcing scenarios on decadal, centennial, and millennium time scales, focusing on understanding the pathways of solar impacts from upper atmosphere through the troposphere and into the land and oceans. By analyzing the GCM simulation results we explore and test recent proposed amplification mechanisms for solar impacts on climate.

Dong Wu/Jet Propulsion Laboratory
Observational Study of Solar Variability Impacts on the Troposphere, Stratosphere and Mesosphere

In response to the LWS Program call on the Sun-Climate Theme, we propose to characterize and investigate impacts of solar variability on short (e.g., 27 days) and long (11 years) time scales with new observations from advanced satellite sensors. We analyze the high-quality solar spectral data acquired by NASA SORCE (Solar Radiation and Climate Experiment) SIM (Spectral Irradiance Monitor) and TIMED (Thermosphere Ionosphere Mesosphere Energetics and Dynamics), as well as global atmospheric data from MLS (Microwave Limb Sounder), MISR (Multiangle Imaging SpectroRadiometer), ISCCP (International Satellite Cloud Climatology Project), and FTUVS (Fourier Transform Ultraviolet Spectrometer), together with long reanalysis records, to derive, characterize and better understand atmospheric and cloud responses to the solar variability at different spectral wavelengths. As indicated in the recent SORCE SIM observations, the increasing of solar irradiance at near infrared spectral bands during the TSI (total solar irradiance) declining phase of solar cycle 23. Impacts of the spectral solar irradiance variations become even more complicated than as originally thought, and atmospheric responses to this forcing need to be investigated as a whole. We propose to explore atmospheric photochemical, radiative, and dynamical processes, and their responses to each spectral region of the solar irradiance variances over the solar cycle, and focus on coupling mechanisms that may act to amplify the solar signals in Earth's climate system. We will explore the solar-cycle responses in the GISS AR5 version of ModelE GCM, which are simulated from new observed spectral solar irradiance variations, to better understand how the coupled mechanisms work by comparing the solar signals from the observations with those from the model simulations.

Fangqun Yu/University at Albany
Climate Impacts of Solar Variation-Induced Changes in Tropospheric Particle Formation, CCN, and Cloud Properties

Sun supplies most of the energy for the Earth's atmospheric and climate system. The meas-ured 0.1% level of the long-term total solar irradiance (TSI) variations (i.e., solar direct effect on climate change) is generally considered to be too small to account for the apparent correlation between observed historical solar variations and climate changes, which may imply an indirect solar forcing unaccounted for. In order to clearly defined the consequences of human activity on climate and accurately predict the climate change on decadal and longer time scales, possible indirect impacts of solar activity on Earth’s climate have to be identified, formulated, and in-cluded in the climate models. The main objective of this project is to investigate solar indirect climate impacts via solar variations-induced changes in tropospheric particle formation, CCN, and cloud properties.

There are two main research objectives of this proposal. The first one is to study impact of solar variations (both TSI and cosmic ray flux) on global new particle formation and cloud condensation nuclei (CCN) concentration, using a recently developed global size-resolved aerosol model (GEOS-Chem +APM). It is well known that particle nucleation rates are sensitive to T, RH, and precursor gas concentration ([H2SO4]). The ion-mediated nucleation (IMN) rates also depend on ionization rates. Our recent global modeling study indicates that IMN may contribute significantly to the number abundance of particles in most part of troposphere. We propose to study the possible response of CCN concentrations to solar variations via nucleation and growth of secondary particles. Our initial study indicates that solar variations can lead to CCN change at a magnitude that can cause important climate forcing. Our second research objective is to incorporate this solar indirect radiative forcing associated with CCN change into the recently released Community Earth System Model (CESM). CESM is a coupled climate model composed of four separate models simultaneously simulating the earth's atmosphere, ocean, land surface and sea-ice, and one central coupler component. The CESM allows researchers to conduct fundamental research into the earth's past, present and future climate states. By including a physics-based mechanism of solar variation-induced change of CCN concentrations in the CESM, we will study the magnitude of this solar indirect radiative forcing under different atmospheric conditions (pre-industrial, present, and future emission and climate).

This project is highly relevant to the strategic objective of the Sun-Climate Theme of the NASA LWS, which is to “deliver the understanding of how and to what degree variations in the solar radiative and particulate output contribute to changes in global and regional climate over a wide range of time scales.”